

Examination of Conceptual Change Research Over A Decade: A Bibliometric Analysis Using Science Mapping Tool

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Abstract

This study aims to deliver a summary of conceptual change research based on scientific production, most relevant researchers and countries, co-authorship collaboration, and research foci. A bibliometric analysis of the scientific output in the field of conceptual change was carried out utilizing articles published between 2012 and 2021. A total of 515 articles published in educational psychology, cognitive science and science education journals were extracted from Scopus databases. The main findings reveal that the number of articles on conceptual change during the 2012-2021 period is relatively constant. Co-authorship collaborations predominantly consist of researchers from the same country. In addition, a shift in the research foci was observed. Past studies have been widely carried out across disciplines, such as educational psychology, cognitive science, and pedagogic. Meanwhile, recent research foci have brought up curriculum and curriculum development as important keywords.

Keywords: bibliometric, cognitive science, conceptual change, curriculum development, science education

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1. Introduction

The complexity that arises while “constructing new notions within the framework of old ones” has been referred to in the educational and educational psychology literatures for quite some time with the term “conceptual change” (Potvin et al., 2020). According to the traditional view of conceptual change, alternative conceptions can be transformed or replaced by more scientifically accurate understandings of phenomena (Mills et al., 2016). Although this statement is simple, the interaction between prior and new conceptions is more complicated. It encompasses one's epistemological commitments as well as metaphysical beliefs con-

cerning science (Posner et al., 1982), and it has evolved over the last three decades to determine several affective factors (Mason & Zaccoletti, 2021). These affective factors have been widely explored by many studies, such as motivation (Taasoobshirazi et al., 2016), confidence in prior knowledge and self-efficacy (Cordova et al., 2014), emotional and attitude (Chancey et al., 2021), and situational interest (Thomas & Kirby, 2020). Some researchers have proposed a multidimensional model of conceptual change that considers epistemological (classical), ontological, and affective aspects (Amin & Smith, 2014). Lastly, the most noteworthy current development in concep-

tual change research was the recognition of the impact of learner attributes on learning as Sinatra (2005) stated as the “warming trend”.

In addition, conceptual change literature has been fully included in numerous instructional approaches widely developed by researchers across the world. Conceptual change texts (Çil & Çepni, 2016; Ozkan & Selcuk, 2016; Sel & Sözer, 2019; Sevim, 2013), refutation texts (Cordova et al., 2014; Djudin, 2021; Franco et al., 2012; Mason et al., 2019; Ranellucci et al., 2013; Yazbec et al., 2019), cognitive conflicts (Dega et al., 2013; Madu & Orji, 2015), analogies (Hanson & Seheri-Jele, 2018; Sevim, 2013), system modelling (C. B. Lee et al., 2011), concept maps (Hanson & Seheri-Jele, 2018), concept cartoons (Çil & Çepni, 2016; Taşlıdere, 2021), concept clipboards (Çil & Çepni, 2016), meaning-making based instructions (Sarioglan & Kucukozer, 2017), and 3-2-1 readings (Djudin, 2021) are, among others, widely implemented in conceptual change context. Several researchers have even integrated some instructional approaches as well. For example, Taşlıdere (2021) examined the relative effectiveness of conceptual change texts with concept cartoons (CCTCC) and 5E learning model with simulation activities (5ESA) on pre-service teachers’ conceptual comprehension of waves.

In specific content, the field has successfully revealed students’ alternative conceptions in many levels of education, such as force and motion (Anggoro et al., 2019; Franco et al., 2012; McLure et al., 2020), buoyancy (Djudin, 2021; Edelsbrunner et al., 2018), simple electric circuits (Dega et al., 2013), genetics (McLure et al., 2020; Yazbec et al., 2019), natural selection (Asterhan & Resnick, 2020; McLure et al., 2020), photosynthesis (Ahopelto et al., 2011), seasonal and climate change (Cordova et al., 2014;

Heddy et al., 2018; Mason et al., 2017), acid-base (Hanson & Seheri-Jele, 2018), chemical bonds (Sevim, 2013), intermolecular forces (Sevim, 2013), and nature of science (Çil & Çepni, 2016). In other words, conceptual change literature is an ocean of important information in science education for science academics. Consequently, it is important to present an overview of up-to-date research output in conceptual change. Therefore, this study was conducted to perform a bibliometric analysis to create the essential summary.

2. Method

The rapid advancement of information technology in the twenty-first century leads to the enhancement in collecting, organizing, manipulating, and drawing assumptions on data (Odewumi et al., 2019). As a result, bibliometric analysis has become popular in science education studies in recent years. Issues such as technology and higher education (Shen & Ho, 2020), quantum physics (Bitzenbauer, 2021), scientific literacy (Effendi et al., 2021), virtual and remote labs (Heradio et al., 2016), STE(A)M (Özkaya, 2019; Syahmani et al., 2021), or the linking behaviour in the network of physics education research co-authorship (Anderson et al., 2017), among others, are bibliometrically analysed. The analysis is adopted since because it helps identify and map collective scientific research topics and provide a comprehensive summary of scientific outcomes and their growth in the investigated field of study over time (Donthu et al., 2021).

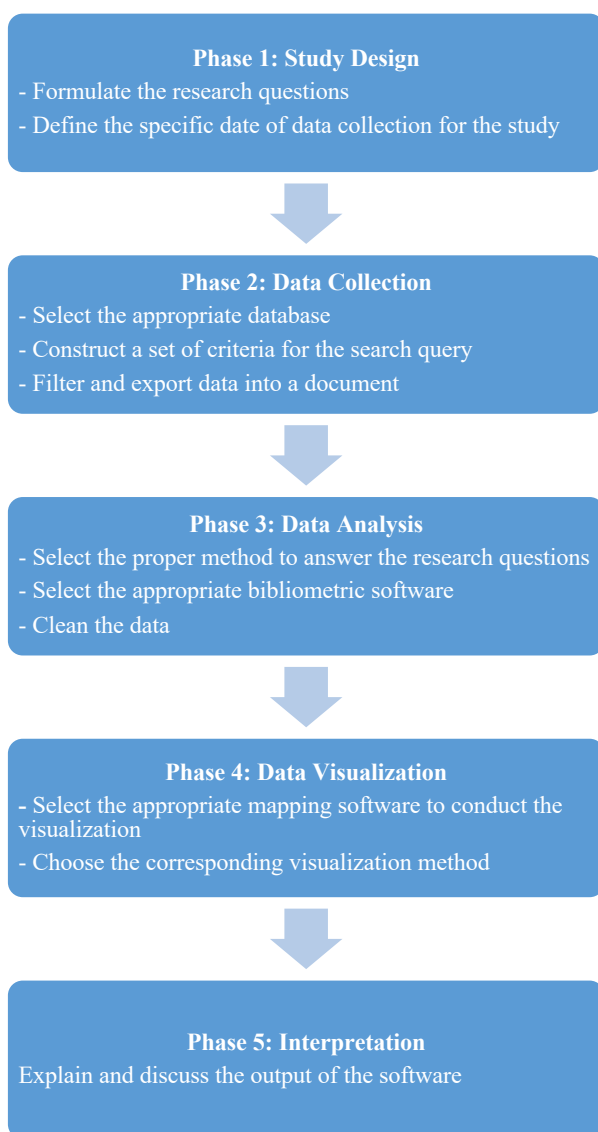


Figure 1. Science mapping workflow using bibliometric analysis

In this study, the standard workflow for science mapping by Zupic and Čater (2015) was adapted as presented in Figure 1. In the following section, the stages in Phase 1-4 are presented sequentially, whereas research findings are addressed in the results section. Interpretation and discussion of the findings are subsequently delivered in the final section.

a. Study Design

Scopus website (<http://www.scopus.com>) was accessed on January 24, 2022 to acquire the bibliometric data. To guide the

bibliometric study, the research questions were formulated as follow (1) How have the publications and articles citation on conceptual change research developed from 2012 to 2021; (2) Which authors and countries were the most relevant in the publication of articles on conceptual change from 2012 to 2021; (3) Is there evidence of extensive collaboration among researchers and countries in conceptual change research from 2012 to 2021; (4) What were the most relevant keywords, and what co-occurrence patterns can be found in conceptual change research from 2012 to 2021.

b. Data Collection

Study data were collected in January 2022. For search queries, a set of data-related common criteria which includes the combination keywords with binary operators such as OR and AND was established. Conceptual change, misconceptions, and science education were the selected keywords for data collection, followed by filtering of article titles, article abstracts and the authors' keywords. In addition, data collection was restricted to studies published between 2012 and 2021, and articles published in peer-reviewed journals. Retrieved data from Scopus were exported in .csv format and processed using the R-package bibliometrix. Table 1 presents an overview of the data used for the bibliometric analysis.

c. Data Analysis and Visualization

Donthu et al. (2021) stated two primary methods of a bibliometric analysis: (1) performance analysis and (2) science mapping. The goal of performance analysis is to evaluate the scientific outcome in a given research area using qualitative (e.g., productivity per active year of publication) and quantitative indicators (e.g., number of contributing authors), associated with the general scientific

community and specific different researchers (Gutiérrez-Salcedo et al., 2018). Science mapping depicts the relationships between various subject areas, documents, or authors of a given research field in a spatial format (Cobo et al., 2012). In light of this, the research questions were answered by utilizing

both performance analysis and science mapping methods. In addition, R package *bibliometrix* was used to perform the bibliometric analysis, VOSviewer was utilized to visualize the science mapping results. Table 2 illustrates a complete summary of the data analysis as well as the software analysis tool.

Table 1. Summary of Data Extraction from Scopus and Data Used in Bibliometric Analysis

Output	Results
Primary information	
Duration	2012 – 2021
Number of sources	186
Number of documents	515
Average years from publication	5.54
Average citations per document	11.47
Average citations per year per document	1.526
Total number of references (without duplicates)	24,526
Total number of author keywords	1,389
Authors	
Number of authors	1,254
Number of authors of singled-authored documents	74
Number of authors of multi-authored documents	1,180
Author collaboration	
Number of single-authored documents	76
Authors per document	2.43
Co-authors per document	2.92
Collaboration index	2.69

Table 2. Summary of Data Analysis and Software Analysis Tools

Research Question	Main Method (Actual Analysis)	Science Mapping Tool
How have the publications and articles citation on conceptual change research developed over time from 2011 to 2021?	Performance analysis (analysis of the number of articles published per year and the number of average article citations per year)	R package <i>bibliometrix</i> ver 3.1.4
Which authors and countries were the most relevant in the publication of articles on conceptual change from 2012 to 2021?	Performance analysis (identification of the most productive authors including their scientific publication over time and the most productive countries)	R package <i>bibliometrix</i> ver 3.1.4
Is there evidence of extensive collabo-	Science mapping (co-authorship analysis)	R package <i>bibliometrix</i>

Research Question	Main Method (Actual Analysis)	Science Mapping Tool
ration among researchers and countries in conceptual change research from 2012 to 2021?		ver 3.1.4
What were the most relevant keywords, and what co-occurrence patterns can be found in conceptual change research from 2012 to 2021?	Science mapping (co-word analysis)	VOSviewer ver 1.6.16

3. Result and Discussion

a. Development of Scientific Output on Conceptual Change in Science Education Research

Figure 2 presents the development of conceptual change studies over time. During the 2012-2021 period, the number of articles

was at a relatively constant number of approximately 50 articles. The highest number of article productions occurred in 2018 with a total of 64 articles. Subsequently, a decrease in the number of article production was observed in 2016 (n = 39) and 2021 (n = 39).

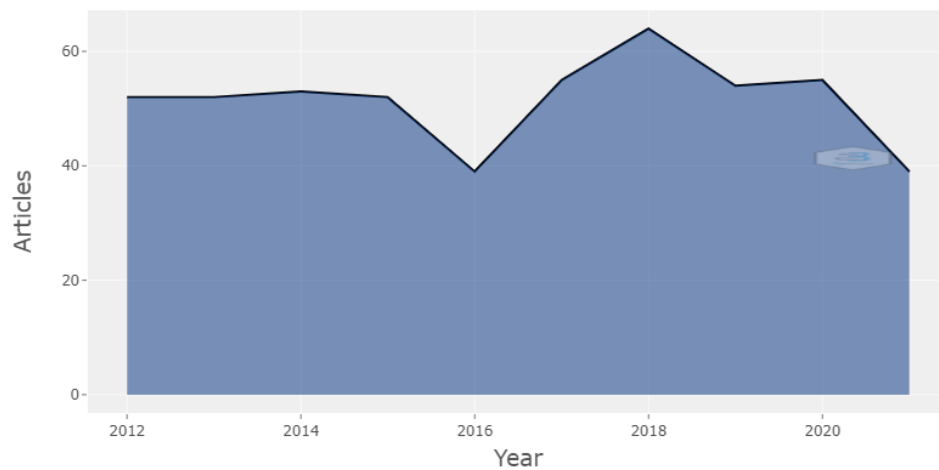


Figure 2. Annual Scientific Production

Of the 1,254 authors recorded within the documents, 135 published at least two articles on conceptual change research in the 2012-2021 period. In addition, 27 authors published three articles, 6 published four articles, and 8 published five or more articles. In other words, almost all authors only

published one article between 2012 and 2021. Each published article was cited an average of 11.37 times. Each publication received approximately 0.80 citations per year on average. The average article citation per year is presented in Figure 3.

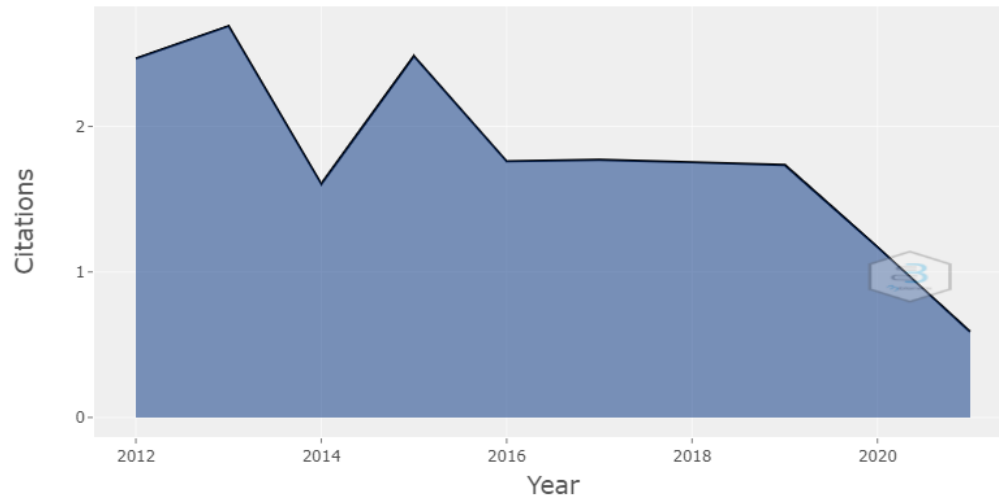


Figure 3. Average Article Citation per Year

b. Leading Researchers and Countries in Article Publication on Conceptual Change in Science Education Research

A further analysis on the most productive researchers in conceptual change research area in terms of articles published and citations between 2012 and 2021 was con-

ducted. The analysis results are presented in Table 3, indicating that Sinatra GM is the author with the highest number of publication and total citation. In addition, Lombardi D and Potvin P have smaller number of publications, but the total citation of these two authors as high as 317 and 159, respectively.

Table 3. Top 10 Most Relevant Authors Publishing on Conceptual Change

Corresponding Author	NP	TC	TC/NP	TCpY
SINATRA GM	10	499	49.9	57.19
SAMSUDIN A	9	78	8.67	15.14
SÖDERVIK I	7	40	5.71	4.95
MIKKILÄ-ERDMANN M	6	65	10.83	7.65
SUHANDI A	6	61	10.17	10.31
CHIU M-H	5	44	8.8	5.78
LOMBARDI D	5	371	74.2	37.32
POTVIN P	5	159	31.8	20.92
BOGNER FX	4	24	6	1.25
DANIELSON RW	4	94	23.5	17.03

Note: TC = Total Citation; NP = Number of Publication; TCpY = Total Citation per Year

Despite the fact that some of the most productive authors have constantly contributed to the field with publications over the last decade, it is observed that others published all of their work in a shorter period of

time, primarily since 2016 as shown in Figure 4. In contrast, Lombardi D, as a corresponding author, has not published any articles since 2016.

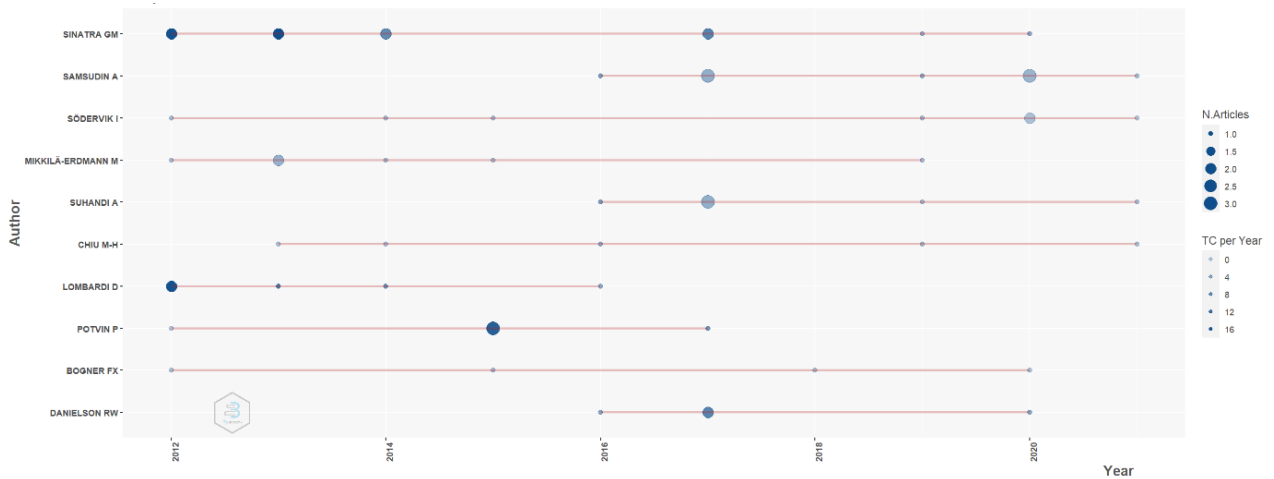


Figure 4. Top Authors' Production over the Time

Since the total number of citations presented in Table 3 also includes citations from outside the conceptual change research area, it is therefore necessary to identify the most significant articles for the conceptual change research community by examining how

many times a given article in the dataset was cited by other authors from the same collection, which is known as the number of local citations. Table 4 presents the ten articles with the highest number of local citations.

Table 4. Top Ten Most Cited Documents Published on Conceptual Change During the 2012 – 2021 Period

Corresponding Author	Publication Year	Name of Journal	LCS	GCS	Doi
SHTULMAN A	2012	Cognition	12	182	10.1016/j.cognition.2012.04.005
CORDOVA JR	2014	Contemporary Educational Psychology	10	63	10.1016/j.cedpsych.2014.03.006
POTVIN P	2015	International Journal of Science and Mathematics Education	8	42	10.1007/s10763-014-9520-6
LOMBARDI D	2013	Learning Instruction	7	101	10.1016/j.learninstruc.2013.03.001
VAN LOON MH	2015	Contemporary Educational Psychology	7	49	10.1016/j.cedpsych.2015.04.003
LEE G	2012	Research in Science Education	7	24	10.1007/s11165-011-9234-5
DURKIN K	2012	Learning Instruction	6	151	10.1016/j.learninstruc.2011.11.001
SINATRA GM	2012	Instructional Science	6	83	10.1007/s11251-011-9166-5
SAMSUDIN A	2016	Asia-Pacific Forum on Science Learning and Teaching	6	36	-
FURNHAM A	2014	Teaching of Psychology	6	22	10.1177/0098628314537984

Note: GCS = Global Citations; LCS = Local Citations

An examination was also conducted on the countries of the corresponding authors, as well as the number of single and multiple country publications in order to present a summary of the countries contributing in the scientific discussion on conceptual change research. The analysis results are presented in Figure 5.

Based on Figure 5, it can be seen that the top ten publishers consist of countries from Asia, Australia, Europe, and the U.S. In other words, research on conceptual change

have been developed predominantly by many authors from wide-ranging regions. Particularly, the majority of publications on conceptual change were written by corresponding authors from the U.S. with a total of 110 articles or more than one fifth of the analysed publications. Furthermore, the percentage of multiple country publication was merely 9.09%. In contrast, Indonesia has the biggest percentage of multiple country publication (26.67%), followed by China (20%), Germany (17.24%), and Turkey (14.63%).

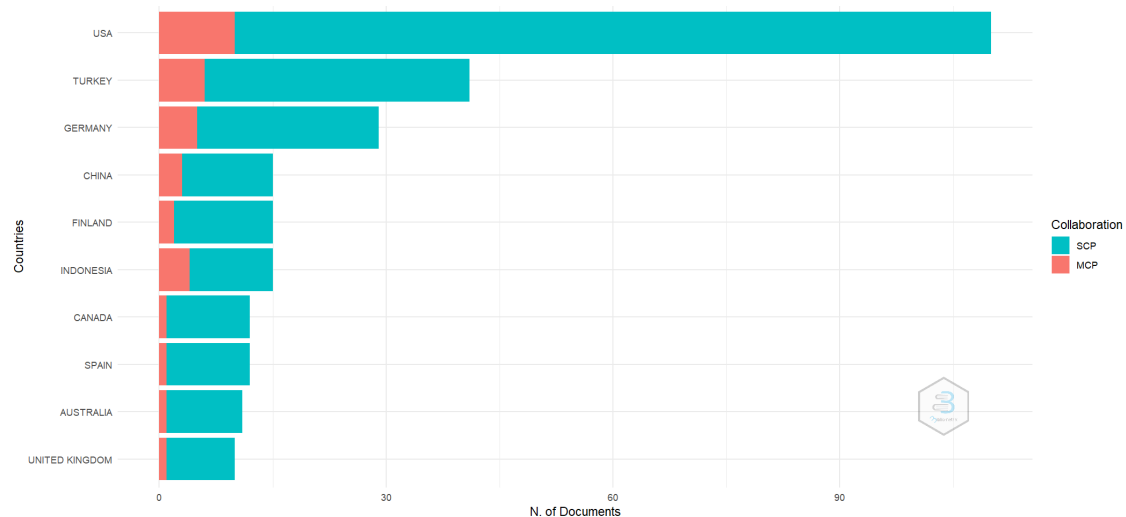


Figure 5. Corresponding Author's Country

c. Collaborations among Researchers and Countries in Conceptual Change Research

Research collaboration has played an important part in scientific productivity (S. Lee & Bozeman, 2005), academic quality (Rigby & Edler, 2005), and the promotion of knowledge construction in modern science, owing to its ability to support the knowledge and skills transfer while also reducing time spent and error occurrences (Ebadi & Schiffauerova, 2015). Not all forms of research collaboration are formally documented in papers (Hargreaves, 2019). Notwithstanding, the number of joint publications may serve as an indicator of academic col-

laboration among researchers (Mahi et al., 2021) since they are positively related (Moed et al., 2004). Thus, a co-authorship analysis was carried out to examine whether researchers in the conceptual change research community cooperate extensively and the analysis results are visualized in Figure 6. Each node in Figure 6 denotes one author and the node size grows in proportion to the number of articles published by the corresponding author. The lines connecting two nodes represent co-authored papers by these authors, while the thickness of the line increases with the number of co-authored articles. The colours express the established clusters.

The research is limited to authors with a minimum of two joint publications in clustering criteria. In other words, the visualiza-

tion excludes authors who have only published single-authored articles.

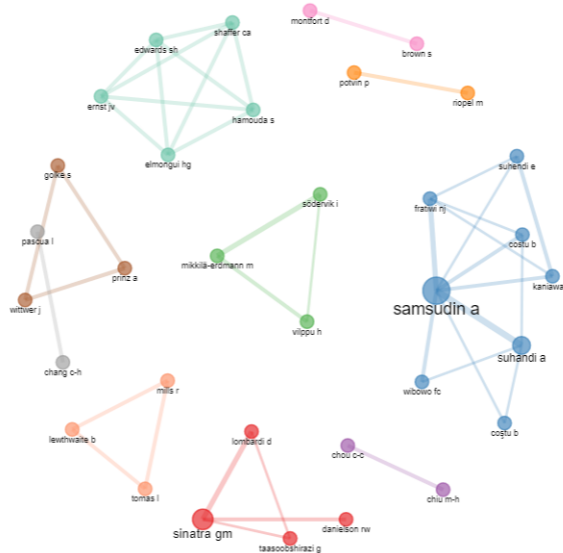


Figure 6. Co-Authorship Network Concentrating on Authors of Conceptual Change Research Publication from 2012 to 2021

Based on Figure 6, it can be seen that there are several prominent disjoint clusters which consist of a few authors. There are even three collaborations between two authors, suggesting that there have been collaborations among conceptual change researchers. Nonetheless, there are no authors in one cluster with extensive collaboration with author from other clusters. For clearer

description, Table 5 is presented to focus on individual cluster analysis. Based on Table 5, the individual clusters mostly consist of authors from the same country. This highlights the evidence that only a small number of international collaborations occurred among conceptual change researcher during the 2012-2021 period. Table 5 supports the results presented by Figure 6.

Table 5. Exemplary National and International Collaboration Among Researchers on Conceptual Change

Clusters	Authors (Country)	Exemplary Publication(s)
Blue	Fратиwi, Kaniawati, Samsudin, Suhandi, Suhendi, Wibowo (Indonesia), Coştu (Turkey)	(Fratiwi et al., 2020) (Kaniawati et al., 2016)
Aqua	Ernst, Edwards, Hamouda, Shaffer (USA), Elmongui (Egypt)	(Hamouda et al., 2020) (Hamouda et al., 2017)
Red	Danielson, Lombardi, Sinatra, Taasoobshirazi, (USA)	(Cordova et al., 2014) (Lombardi & Sinatra, 2012) (Sinatra et al., 2012)
Rose	Lewthwaite, Mills, Tomas (Australia)	(Mills et al., 2019)
Brown	Golke, Prinz, Wittwer (Germany)	(Prinz et al., 2021)
Green	Mikkilä-Erdmann, Södervik, Vilppu (Finland)	(Mikkilä-Erdmann et al., 2012)
Light Orange	Potvin, Riopel (Canada)	(Potvin et al., 2015)
Orange		(Brault Foisy et al., 2015)
Grey	Chang, Pascua (Singapore)	(Chang et al., 2018) (Chang & Pascua, 2016)
Purple	Chiu, Chou (Taiwan)	(Chiu et al., 2019)
Pink	Brown, Montfort (USA)	(Brown et al., 2018)

d. Keyword Co-Occurrence Patterns in Conceptual Change Research

According to frequency analysis, the most frequently discovered keywords in the articles were “misconceptions” (310 times), “conceptual change” (235 times), and “science education” (35 times). These terms are extremely broad and neither allow the identification of the primary research themes in the field nor the tracking of how they have shifted over time. Therefore, a co-word analysis was carried out to reveal co-occurrence patterns which enabled deeper perspectives, since co-word analysis generally investigates the concrete content of the publication itself (Donthu et al., 2021). In other words, the presumption underlying a co-word analysis is that thematic relationships among keywords occur when the words appear frequently together (Donthu et al., 2021).

VOS viewer software was used to visualise the results of the co-word analysis. The software generated a two-dimensional map after the calculation of a similarity matrix based on a normalized co-occurrence matrix. To obtain the complete data, terms derived from the article titles, the abstracts, and the author keywords in the co-words analysis have been included. However, only terms that occurred in a minimum of three articles for the co-word analysis were included. Of the 1390 keywords, 131 satisfied the requirement. Subsequently, two terms (“students” and “education”) with low relevance value and obtain no additional content were manually excluded. As a result, 129 terms remained for mapping. The complete co-word network is visualized in Figure 7.

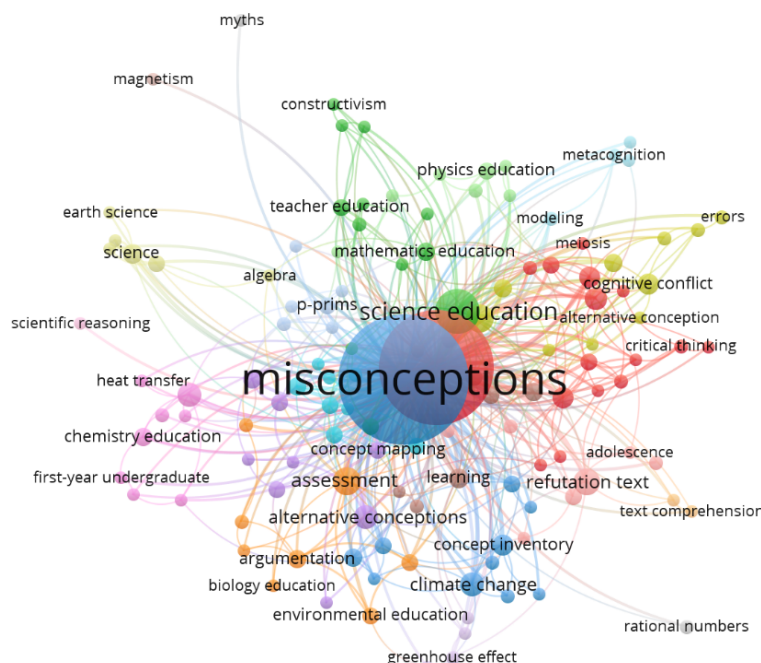


Figure 7. Final Visualization of Co-Word Analysis

In Figure 7, the font size represents the relative frequency of term occurrence, and the connecting lines represent keyword co-occurrence. Term clusters that appear repeatedly are highlighted in similar color. The co-

word analysis reveals numerous clusters that are not mutually exclusive. The red and blue are two primary clusters which dominate the mapping. The blue cluster is the largest cluster consisting of eleven terms, such as “mis-

conceptions”, “active learning”, “mental models”, “preconceptions”, “recursions”, etc. Meanwhile, the red cluster consists the most terms, such as “conceptual change”, “critical thinking”, “engagement”, “higher education”, “interest”, etc. Nevertheless, the red cluster does not have both occurrence and link strength as high as the blue cluster. In addition, both these primary clusters link to mostly other clusters and indicate the interdependency of these two pillars. On other hand, these two clusters also allow the identification of two main pillars of conceptual change studies.

Surprisingly, the green cluster appears on the second position in the context of number of terms, although this cluster indicates a lower link strength than the blue cluster. The green cluster mainly highlights participants’ educational level of conceptual change research. Lastly, in a more thorough observation, it was discovered that three clusters only include one term, namely “magnetism”, “scientific reasoning”, “myths”, and “rational number” which link to misconceptions and/or conceptual change term. The co-words analysis for conceptual change research concluded that each cluster does not indicate a specific theme since it consists of various aspects of conceptual change research as previously mentioned for the red, blue, or green cluster. It suggests that conceptual change studies have extensively investigated various learner characteristics, examined students of various educational levels, implemented several instructional approaches, and matched with all science education content.

The sequential shift of conceptual change research theme was further explored by converting Figure 6 into an overlay visualization. The VOSviewer software calculated the average publication year based on the publication year of the articles, which was

then linearly transformed into a scale ranging from 0 to 1 represented in colors. Figure 7 shows the corresponding overlay visualization.

Figure 8 shows a shift on the main focus of conceptual change research over the average years. Majority of the terms, the primary terms in particular, were published in old publications. Some aspects of conceptual research have not been studied in recent years, while others are under examinations. Subject matters such as climate change, greenhouse effect, natural selection, algebra and photosynthesis are included in past research cluster (average publication year of 2015) and barely examined in recent years. On the other hand, meiosis and magnetism are among the topics discovered in recent research clusters (average publication year of 2019). Meanwhile, instructional context, conceptual change text, textbook, analogy, curriculum (development) and constructivism have an average year of 2013 and rarely contributed in recent conceptual change research. In addition, multiple representation and refutation text with average year of 2019 still exist and contribute in recent conceptual change studies.

Learner characteristics and abilities, attitudes, argumentation, (pre)conceptions, engagement, and scientific argumentations were frequently examined in old publications since they have average year of 2015 and are undiscovered in recent conceptual change studies. In contrast, belief, metacognition, text comprehension, meta-comprehension accuracy, problem solving are identified in recent conceptual change studies since they indicate average year of 2019. Figure 7 illustrates that researchers mostly involve primary school students, high school students, and first year undergraduates in conceptual change studies. Meanwhile, pre service

teachers are involved in both past and current conceptual change studies.

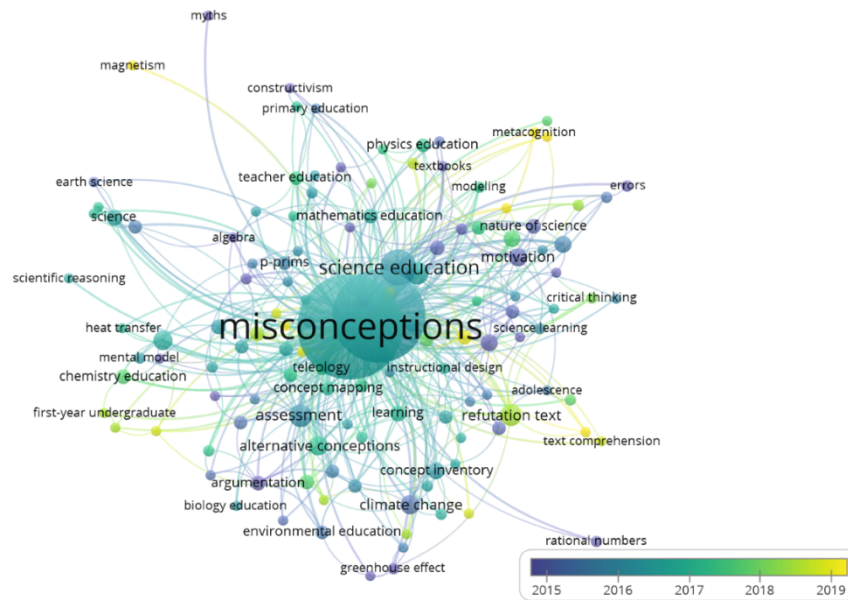


Figure 8. Overlay Visualization of the Co-Word Analysis Results

The main results of research questions are summarized following a discussion on the possible direction to contribute in developing future conceptual change research as follows.

Research Question 1: The number of articles is at a relatively constant number of approximately 50 articles. The highest number of article production occurred in 2018 with a total of 64 articles and a decrease in article production was observed in 2016 and 2021.

Research Question 2: Majority of publications on conceptual change were written by corresponding authors from the U.S. It is in accordance with the results indicating that the list of most relevant authors in conceptual change research was led by authors from the U.S., namely Sinatra GM as the most active and most cited author and Shtulman as the author with the most local citations. Nevertheless, the U.S. only represented a small percentage of multiple-country publication. In contrast, Indonesia represented the highest percentage of multiple-country publication, followed by China, Germany, and Turkey.

The results on research question 1 and 2 serve as a hint for future development of researchers in conceptual change from wide-ranging countries. These results may stimulate the researcher community with respect to the scientific publication on conceptual change in highly-regarded journals as the future potential task, since many authors and countries have contributed to develop the field. In particular, a few have started multiple-country collaborations in publishing scientific results on conceptual change. This growth is in accordance with the response that uncovering the occurrence of conceptual change has been a prodigious agenda for science academics since the 1980s (Gao et al., 2020). In addition, investigating students' misconceptions is regarded as a crucial teaching pedagogy in science learning (Schroeder, 2016). The efforts will help close the gap with the U.S, which is currently in the lead.

Research Question 3: The researcher community on conceptual change has not established a strong international collaboration yet. Instead, some researchers have par-

ticipated in several smaller and mostly national co-authorship initiatives.

It is believed that the results of the co-authorship analysis (see Figures 6 and Table 5) are important data for the research community since they demonstrate the need for stronger (multinational) collaboration to improve the field. The efforts are not impossible since many previous studies have shown the development of research collaboration (Glänzel, 2001; Wagner, 2004). For example, the proportion of internationally co-authored papers doubled in the 1990-2000 period. Several studies have found that scientists in developing countries are not excluded from the global research community (Steenwerth et al., 2014), and that the number of international co-authors in both developed and developing countries has increased in last decades (Khor & Yu, 2016). In addition, Nagendra et al., (2018) proposed that international collaboration is critical in developing countries' efforts to build scientific capacity.

One way to respond the study results is to form a research community on conceptual change as a forum for world researchers to carry out further collaboration. This can be initiated by researchers from the U.S. as the most productive country in conceptual change research. This process has appeared in other fields, such as quantum physics education within the European Quantum Flagship.

Research Question 4: Conceptual change research includes numerous connected terms and co-words analysis cannot specify the established clusters. Conceptual change is the most common aspect in learning, and educational psychology, cognitive science, as well as instructional science have broadly influenced the research foci. Consequently, many researchers have integrated numerous aspects in examined conceptual change.

In the introduction section, the long and exhaustive efforts of conceptual change researches since 1970s have been highlighted. Several research domains have widely contributed to determine the nature of conceptual change and academics have implemented numerous instructional approaches to facilitate students' conceptual change. It is in accordance with the co-words analysis results which consist of various clusters with several aspects of research foci.

Co-words analysis reveals the occurrence of new terms currently included in conceptual change research, namely "curriculum" and "curriculum development". Curriculum plays the strategic role in teaching and learning process. Considering many instructional approaches have successfully facilitated students' conceptual change and factors influencing student's conceptual change have been explored by educational psychology field, it is the right time for conceptual change to be inserted in science education curriculum. It is relevant with previous studies which proposed the revision of teaching methods and content of textbooks for related unsuccessful parts in several topics in science domain (Al-Rsa'i et al., 2020; Edelsbrunner et al., 2018; Rochintaniawati et al., 2019; Stieff & DeSutter, 2021). As for other subjects besides science, the results only indicate geography learning was involved in the research during the 2012-2021 period. In other words, conceptual change has not been an emerging aspect in other subjects of research.

Further co-words analysis also discovers that teacher preparation on conceptual change learning have rarely been examined in recent studies. It can be observed from terms such as "teacher education", "teacher program", "pre-service (biology) teacher" that were included in old average year clusters. Therefore, teachers should be well pre-

pared to implement successful curriculum oriented on conceptual change. Several studies show that teachers do not have inadequate understanding of scientific idea (Anisimova et al., 2020) and others reported that students and teachers have the same naïve idea (Soeharto et al., 2019; Chancey et al., 2021). This study proposes that future researches on conceptual change to keep exploring both pre-service teachers' and teachers' preparation in implementing conceptual change learning. It is consistent with previous studies (e.g Darmawan & Suparman, 2019; Hermita et al., 2021; Rapanta et al., 2020) that a closer examination of science teachers' preparation is required to assist students in achieving various learning objectives. In addition, teaching is a complex and demanding intellectual task that cannot be achieved without proper preparation (Yusuf, 2022).

4. Conclusion

In conclusion, the results of this study may contribute to future development on conceptual change field and trigger researchers both in terms of research foci and multinational co-authorship. The exhaustive literatures on conceptual change have inspired this work, with the goal of providing a vision that explains the current state of the scientific literature on this subject and the shift to its emerging state.

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